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Planetary Radar

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This article reports on the radar astronomy activities supported by the Deep Space Network during June, July, and August 1980. The planetary bodies observed were Venus, Mercury, and the asteroid Toro. Data were obtained at both S- and X-band, and the observations were considered successful.

The high power S- and X-band transmitters at the Goldstone 64-m station were used to support five different radar observations during this period:

(1) Venus S- and X-band alternating.

(2) Venus tristatic.

(3) Venus rain.

(4) Mercury bistatic.

(5) Asteroid Toro.

I. Venus S- and X-Band Alternating

This was the first time that this particular experiment had been tried. The objective is to do ranging on Venus at two different wavelengths, one of which is not significantly absorbed by the planet's atmosphere and the other which is absorbed greatly by the atmosphere, e.g., only 10 percent returns.

To be successful, it is essential that the ranging for both wavelengths be done on the same day so that the same "windows" of atmosphere are viewed. Also necessary for this absorption measuring experiment is the accurate calibration of station operating parameters such as system noise temperature, transmitter output powers, and antenna pointing accuracy.

This differential absorption observation attempts to utilize the fact that the synodic period of Venus is very nearly in synchronism with the orbital period and so there should be a high correlation between the planetary figure and the orbital parameters. If the planet could be monitored for a full rotation, this would yield continuity of coverage and closure. How does this help?

If the atmospheric constituents are known, then ranging can be done very accurately. It may be possible to measure and monitor the local surface gravity. There is very little known to date about the lowest few kilometers of atmosphere surrounding the planet. This experiment could help to "calibrate" the atmosphere and determine the absorption of the clouds.

There are a couple of technical problems in the way of total success of the experiment, namely:

(1) The X-band transmitter has only one klystron final amplifying tube at this time, the second one being with the manufacturer undergoing repair, so the output power is degraded by 3 dB.

(2) All the X-band spectra are not accumulated because the XDS 930 computer has insufficient memory, which appears as a lack of bandwidth and is overcome by folding over these X-band spectra.

In addition, due to scheduling difficulties, it was not possible to obtain coverage of one full planetary rotation, but the data acquisition was considered fairly successful and, at the present time, analysis and calibration programs are being developed. There are no definite answers from this first Differential Absorption Experiment. How well the algorithms work will be tested soon and the experiment procedures will become less "experimental." After looking at just a couple of segments of data, the planet appears incredibly smooth.

In the future, we hope to calibrate the atmospheric profile of Venus, determine some of the surface properties of the planet, and even detect debris scale size differences. In 1981 and 1982 there is reason to hope that the scheduling pressures will abate sufficiently to permit a full rotation to be observed.

This Deep Space Network capability at the Goldstone 64-m antenna station is the only radar calibrated well enough to give the power sensitivity accuracy required by this experiment.

II. Venus Tristatic

This activity utilizes, in addition to the high-power, S-band transmitter at the Goldstone 64-m, antenna station, the S-band receiving systems at the Goldstone 64-m and the two 26-m antenna stations. The received echoes are down-converted in frequency and modulated on to a microwave channel from the remote 26-m antenna stations to the 64-m antenna station for common formatting, timing, and recording.

The objective is to measure relatively high-resolution simultaneous altitudes and reflectivities to further understand the geology of the planet.

The altimetry is accurate enough to detect small volcanoes not seen by the Pioneer-Venus spacecraft. Pioneer pixel resolution is a 30-km square, whereas tristatic radar can resolve to an 8-km square. Because the altimetry is so good, it is possible to see isostatic compensation of the surface; for example, the outer slopes of a couple of volcanoes appear to be compensated. Questions that arise are: How big are the slopes? How well are they compensated? How smooth?

Data for this experiment, which has been going for several years, are now coming in at handling rate and modelling can start. For the first time, good reflectivity and altimetry data are being acquired simultaneously.

The reflectivities are very dependent upon the area of the surface and can be used to determine something of the surface roughness and dielectric constant of the surface material. During this series of experiments, it was hoped to study the effects of angular dependence on the surface and to measure accurately the position of features, using their repeatability to help refine the spin axis. On June 14, a crater was observed exactly as it had been observed in 1972; these are the longest radar repeat scans. The exactitude and eight-year span takes care of the orbital geometry in these measurements. It may be possible to increase resolution by optimization of doppler resolution.

The Deep Space Network is the only network in the world having three systems with adequate sensitivity and baselines to perform this experiment.

In the future, it is hoped to achieve resolution improvement down to 1-km squares. The technological improvements necessary to support science of this quality include a high-speed computer, an array processor, and a high-speed data recorder.

III. Venus Rain

This activity utilizes the facilities of the Goldstone 64-m antenna station only, including the high-power X-band transmitter, which is temporarily capable of outputting only half its rated power because one of the two final amplifier klystron tubes is at the manufacturer's for repair.

The objective of this experiment is to determine if there is any rain in the upper atmosphere of Venus and, if there is, what can be determined about its distribution size and backscattering properties?

It is a difficult experiment because Venus scatters back an immense amount of power on its own account. What is needed is the use of a superspectrum analyzer in the hope of detecting "stuff" (back-scattered power) at the skirts of the planet, although our "stuff" is dwarfed by the planet's "stuff". Scattering from the drops of rain is predicated to have a Rayleighian distribution, which would indicate very small drops; therefore, the shortest wavelength available, presently X-band, is used.

During this series of observations, unexplained power has been detected at the sides of the spectrum; it is too early to state that this is rain; extensive calibrations and more development work are being done to determine the cause of this power.

In the future it is planned to do more of the same type of experiments, and the chances of detection would be enhanced by improving the X-band capability, i.e., restoring the second klystron tube, and by the introduction of a K-band capability.

IV. Mercury Bistatic

This experiment utilized the S-band receive capabilities of the Goldstone 64-m antenna station and the Goldstone 26-m antenna Research and Development station as well as the high-power S-band transmitter.

The objective of this activity was to acquire sufficient data to be able to resolve the planet's spin vector. The spin vector is not known well, the rotation rate being fairly well defined, but the pole direction is only known to within ±6.5 deg. It is hoped that the pole is perpendicular to the orbital plane, but it will be exciting to try and explain it, should it prove to be otherwise. The spin vector is assumed perpendicular to the orbital plane.

The method used is measurement of the velocity and direction of the diffraction pattern received at earth, at two stations operating as an interferometer, using a continuous wave transmission. Early results indicate that interference fringes were found and the correlation function is more flat-topped than had been expected.

In the future, it is proposed to do the same experiment using two techniques: (1) collect old data with limb-to-limb bandwidth measurements and (2) to improve X-band sensitivity, collect more limb-to-limb data, then attempt to fit these data. Possibly an improvement could be effected in the use of the interferometer, e.g., could doppler data yield more than continuous wave?

The Deep Space Network offers the advantage of long observing periods in experiments of this type, and many more such observations will be requested in the future.

V. Asteroid Toro

This asteroid is a small one that was radar detected in 1972. It returns to earth's vicinity every eight years or so. The activity involves only a single station, that being the Goldstone 64-m antenna station including the high-power X-band transmitter and two receiving systems, each looking at a different polarization.

The objective of radar probes of asteroids is to determine what they are, where they come from, and what are they made up of. Optical observations of asteroids only reveal information about the first few microns of the surface. Radar, we hope, will be able to tell more by taking advantage of the close approach to beam pulses of energy at the body and then track the echoes. Asteroids may be left-over pieces of comets, just big pieces of "clinker" with all the volatiles boiled out. One objective is to see in what ways they differ from terrestrial surfaces and the surfaces of the moons of Jupiter.

These bodies are moving so fast at closest approach that, to track them, an ephemeris-tuned oscillator must be used. Such an oscillator exists at the Goldstone 64-m antenna station and it is to be found in the Advanced Systems area; however, for this particular observation, dual polarization was required, and this capability exists only in the operational area of the station, thus it was necessary to make some engineering changes to support the activity. These changes were planned and configured very smoothly, but the attempt to run two polarizations encountered another problem; it takes about 30 seconds to refocus the subreflector each time. This time was lost from each echo, quite an impact with a round-trip light time of the order of 150 seconds.

The experiment requires the use of X-band because asteroid echoes are incredibly weak. The cross-polarized component is expected to be about one-quarter the strength of the normal component. It is essential to have both klystron tubes functional for the next time such an observation is scheduled.

In the future, it is desirable to probe as many close-passing asteroids as possible and, eventually, as the technique and technology improves, to study comets by the same means. This activity may require fast scheduling and reaction time by the Deep Space Network as exemplified in the probe of comet 1979L Bradfield earlier in the year.

The advantages of using Deep Space Network facilities for this work are in tracking time (one evening is sufficient to observe a full rotation of most asteroids) and the shorter wave length of X-band.

In summary, a very successful season has been enjoyed in data acquisition for this activity. A total of some 700 hours of support by stations left some data processing to be done and results and publications are eagerly awaited.